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## Original Articles.

# THE RELATION OF THE NERVOUS SYSTEM TO THE TEMPERATURE OF THE BODY.

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THAT the nervous system has an influence upon heat-production has been known since the time of Brodie, who called the attention of the profession to the rise of temperature seen after a lesion of the spinal cord. He believed the central nervous system to have an immediate influence on heat-production. The proofs that the nervous system has a direct action on the heat of the body may be classed, for purposes of study, into thermometric, chemical, and calorimetric. Thermometric facts: Tscheschichin was the first to announce the existence of an inhibitory heat-centre in the nervous system. In rabbits, after he divided the spinal cord, there was a fall of temperature, but after he divided the medulla from the pons there was a rise. He believed the rise of temperature to be due to the removal of a nerve-centre in the higher parts of the brain inhibiting the thermogenic centres. Nauyn and Quincke found in dogs that after section of the spinal cord there was at first a fall of temperature, which was followed by a rise. They attributed this to an actual increase of heat-production, which, in time, overcame the dissipation engendered by vaso-motor paralysis. Parinaud found, after section of the spinal cord, in rabbits, a continuous fall in temperature, especially of the deeper parts of the body. Schreibler discovered, after injury of the pons in all its parts, the cerebral peduncles, the cerebrum, and cerebellum, an increase of the temperature of the body, when heat-dissipation was prevented by artificial means. The rise of temperature was constant after an injury between the medulla and the pons; he used rabbits. Eulenberg and Landois found an increase of temperature after removal of the cortex cerebri about the sulcus cruciatus. Prof. Hitzit has arrived at similar conclusions. Chemical facts: In dogs, Leyden and Fränkel found the carbonic acid increased in fever. Colasanti and Pflüger found cold to increase the amount of carbonic acid and the absorption of oxygen, which has been confirmed by Sanderson, Röhrig, and Zuntz. It was discovered by the two latter observers, that in poisoning with urari there was a marked diminution in the consumption of oxygen and the excretion of carbonic acid; the bodily temperature also fell, even when prevented by external preventive measures. In the uninjured animal the external cold excites some sensory nerves which, conveying impressions to the central nervous apparatus, cause it to send out afferent impulses to the muscles, increasing tissue-metamorphoses, and thus furnishing more heat. But when the nerves going to the muscles are paralyzed by urari, then these efferent impulses can not reach the muscles, and no increment of tissue-change takes place upon the application of cold. The experiments of Pflüger and his pupils tend to show that there is a nervous apparatus by which external cold increases the tissue-metamorphoses, and thus generates more heat. Hence chemical data support the thermometric, and the view of Tscheschichin, that there is a nervous apparatus to inhibit thermogenic centres. From this stand-point fever is supposed to cause a paresis of the inhibitory mechanism allowing the thermogenic centres to come into play of exaggerated activity. Colasanti found in the guinea-pig that, in pyrexia, the usual reaction did not ensue upon the application of external cold. Finkler has made a very exhaustive study of the phenomena of fever, and deduced the law that the consumption of oxygen is increased during fever, and that there is an increase of carbonic acid due to increased heat-production. He also arrives at the conclusion that fever is a neurosis, mainly a disease of a nervous system regulating the temperature. Calorimetric facts: Profs. Senator, Leyden, and Wood have studied the matter by means of the calorimeter. Senator found in fever an increased heat-production, which has been confirmed by Prof. Wood's numerous experiments on the subject. Wood is the only one who has calorimetrically studied the effect of sections in a transverse direction of the nervous system from the spinal cord upward at different levels. He confirms Tscheschichin's theory, that the inhibitory heat-centre is probably in the pons varolii. Hence thermometric, chemical, and calorimetric proofs go to show that the phenomena of heat are dominated by the nervous system.

My plan has been to make transverse sections of the brain, not from below but from before backward. The experiments were made on rabbits and cats. The apparatus used was d'Arsonval's calorimeter and Voit's respiration-apparatus. The calorimeter is composed of two concentric conical cylinders forming two cavities: the central one is the inclosure for the animal; the other annular cavity is filled with distilled water, which uniformly distributes the heat around the inclosure containing the animal, and prevents sudden variations of temperature. The external copper wall of the calorimeter has a tube on one side which communicates with the water cavity, and is closed externally by a vertical rubber membrane, which is the only portion of the calorimeter that can be pushed outwardly by the variations in the volume of the water, the apparatus being closed. To the side-tube of the calorimeter, is attached the gas-mechanism. The gas is carried by a tube which normally opens at the centre of the rubber membrane. At a small distance from the gas-tube there is an exit-tube, which permits the gas to escape from the brass box to the burners, which heat the calorimeter. The gas-tube and rubber membrane form a sort of stop-cock of a very sensitive nature, and whose amplitude of openness is dependent upon the variations in the volume of water, which only allows the gas-burners to consume a quantity necessary to compensate the dissipation of heat. In this combination the combustible warms directly the water, which, being the regulator, in its turn, reacts directly upon the combustible gas. Between the two concentric cylinders, passing through the water, is a hollow tube conveying air, one end of which opens externally, and the other in the inclosure containing the animal. In my method of experimentation, part of the air supplied the animal was conveyed to it through this tube.

The management of the apparatus was as follows:

The annular space between the two copper cylinders was filled with water by the external orifice. In this orifice a thermometer was placed, it being arranged so as to allow the escape of the heated water, not closing the aperture; the tubes of rubber going to the burners are adjusted, the gas-tube is screwed against the rubber membrane; when the thermometer attains the desired temperature, it is removed and the space occupied by enough water to fill the cavity made vacant by the thermometer. Then the orifice is closed either by a rubber stopper containing in it a thermometer-bulb, or a rubber stopper perforated with a hollow, glass tube permitting the water to rise in it. The apparatus is now regulated for this temperature by the following mechanism: one tube, which conveys the gas, carries a small movable disk, which applies itself against the rubber membrane, and tends without cessation to remove it from the orifice of the gas-tube, this action being due to a small spring, upon which the disk rests. The water, enlarging in volume, mounts up the glass tube, and this column of water exerts upon the rubber membrane a pressure more or less strong, which gradually antagonizes the elasticity of the spring, and brings the membrane more and more against the orifice from which the gas escapes. There is a constant play between the variations in the volume of the water and the amount of gas given to the gas-burners: the more the water expands the less gas is consumed, and *vice versâ*. To obtain the full sensitiveness of the apparatus, a solid rubber cork is used, instead of one with a glass tube, for the external orifice. This apparatus, upon testing, will remain nearly fixed in temperature for a long time. Geissler's thermometers were used, after having been carefully tested at the Yale Observatory and the necessary corrections made. The temperature of the animal was taken by a rectal thermometer, which was inserted fifty millimetres at each trial.

To close the space occupied by the animal a brass door inclosing a glass and lined at its edge by rubber was used. The closure was made air-tight by screws and bolts.

The calorimeter had its central exit-tube attached to the main air-tube of Voit's respiration-apparatus, through which the air of the calorimeter was aspirated by means of the water-wheel driving the great meter. To describe Voit's apparatus would require too much space. My instrument was made under Prof. Voit's direction, and its management as well as the estimates of carbonic acid and water were carried out as laid down by him in the *Zeitschrift für Biologie*, Band xi., Heft, 4. The method pursued was as follows: The animal was placed in the calorimeter and the change in the rectal thermometer noted as well as the amount of air aspirated from the calorimeter. After an hour or two the animal was removed, etherized, and a transverse section in the brain was made. When it had recovered from the ether it was again placed in the calorimeter and the same changes as heretofore noted. All experimentalists hitherto have made transverse sections of the central nervous system from the spinal cord upward. The plan I pursued was to commence at the anterior part of the brain and to go backward. The skull was broken up by a bone forceps and the "seeker" introduced, the section being made by its blunt-edge. The small "seeker" penetrated the cortex with but little injury to it, and when it reached the base of the brain was drawn transversely so as to divide the parts without injuring the cortex of either side. At the side of entrance the blunt instrument made an injury of but a few millimetres in extent.

In *Experiment* 1 the temperature at the end of the experiment was the same as at the end of the normal observation—that is, 104°. Here the olfactory bulbs were divided. When a transverse section was made behind the corpora striata the temperature was as follows: In exp. 3 the rise was $4\frac{7}{8}$°, in exp. 4 the rise was $4\frac{2}{8}$°, in exp. 7 the rise was 1°, in exp. 8 the rise was $1\frac{7}{8}$°, in exp. 10 the rise was $2\frac{2}{8}$°, in exp. 11 the rise was $2\frac{1}{16}$°, whilst in exp. 5 the fall of temperature was $\frac{2}{8}$°, probably due to shock. When a transverse section was made through the middle of the corpora striata, in exp. 2 there was a rise of 7°, in exp. 6 a rise of $1\frac{5}{8}$°, whilst in exp. 12 there was a fall of $6\frac{3}{8}$°. If an observation was made on the day following a section behind the corpora striata, the rise in exp. 11 was $1\frac{14}{16}$°, showing that the rise of temperature is not wholly temporary. That this rise is not due to injury to the convolutions of the brain is shown by the following experiments: In exp. 9 the convolutions of one hemisphere were destroyed and the fall of temperature was $3\frac{2}{8}$°, whilst where the sulci cruciati were destroyed, as in exp. 14, there was no change in the temperature, but when a section was made through the middle of the corpora striata the rise of temperature was $\frac{4}{8}$°, notwithstanding the removal of the sulci cruciati.

In exp. 13 the convolutions of both hemispheres were destroyed anterior to the sulci cruciati, and the temperature fell $\frac{7}{8}$°.

All these experiments lead up to the conclusion, that in the vicinity of the corpora striata are centres which have a relation to the temperature of the body.

Whether the rise of temperature here is due to heat-dissipation being lessened or to increased heat-production I am not able to say. By a different arrangement of the calorimeter I propose to determine it. The analyses of carbonic acid were too few to draw conclusions from.

It is known in man that a very extensive lesion of the internal capsule is often followed by a very marked rise in the temperature of the body.[1]

Appended are the experiments upon which the preceding statements are based.

C. T. means calorimeter temperature; R. T. rectal temperature.

In the second observation on the same day the calorimeter temperature is not given, because it is the same as in the normal observation. If it differs, from that of the first or normal observation it is noted.

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[1] Ranney: The internal capsule reprint. 1883.

*Experiment* 1.

| TIME. | CALORIMETER T. | RECTAL T. |
|---|---|---|
| 1:15 P.M. | 88.86° | $102\frac{3}{8}^\circ$ |
| 2:30 " | | $104\frac{3}{8}^\circ$ |
| | | 605.7° |
| 3:44 P. M. | | $101\frac{1}{8}^\circ$ |
| 4:59 " | | $104\frac{3}{8}^\circ$ |
| | | ° |

Rabbit: section of olfactory lobes just as they emerge at the anterior edge of the brain. Weight $2\frac{7}{50}$ lbs.

*Experiment* 2.

| TIME. | C. T. | R. T. |
|---|---|---|
| 12:25 P.M. | 84.86° | $101\frac{1}{8}^\circ$ |
| 1:55 " | | $104\frac{4}{8}^\circ$ |
| 3:15 P.M. | | $104\frac{3}{4}^\circ$ |
| 4:30 " | | $111\frac{1}{2}^\circ$ |
| | | 7 ° |

Cat: weight $5\frac{11}{50}$ pounds. Transverse section through the middle of the corpora striata.

*Experiment* 3.

| TIME. | C. T. | R. T. |
|---|---|---|
| 12:25 P.M. | 74.50° | $102\frac{3}{8}^\circ$ |
| 1:40 " | | $102\frac{3}{8}^\circ$ |
| | | 611.5 |
| 2:30 P.M. | | $106\frac{7}{8}^\circ$ |
| 3:45 " | | $107\frac{2}{8}^\circ$ |
| | | $4\frac{7}{8}^\circ$ |

Rabbit: weight $3\frac{29}{50}$ pounds. Transverse section just behind the corpora striata.

*Experiment* 4.

| TIME. | C. T. | R. T. |
|---|---|---|
| 2:38 P.M. | 77.30° | $103\frac{3}{8}^\circ$ |
| 3:38 " | | $103\frac{4}{8}^\circ$ |

| | |
|---|---|
| 3:55 P.M. | $103\frac{7}{8}^{\circ}$ |
| 5:10 " | $107\frac{3}{4}^{\circ}$ |
| | $4\frac{2}{8}^{\circ}$ |

Weight of rabbit, $4\frac{29}{50}$ lbs. Transverse section destroying anterior part of optic thalami and posterior half of corpora striata.

*Experiment* 5.

| TIME. | C. T. | R. T. |
|---|---|---|
| 1:45 P.M. | $77.10^{\circ}$ | $102\frac{5}{8}^{\circ}$ |
| 3:00 " | | $103\frac{2}{8}^{\circ}$ |
| | | $\frac{3}{8}^{\circ}$ |
| 3:35 P.M. | | $102\frac{2}{8}^{\circ}$ |
| 4:50 " | | $103^{\circ}$ |
| | | $\frac{2}{8}^{\circ}$ |

Rabbit: weight $2\frac{45}{50}$ pounds. Section crushing a part of thalami, and a part of corpora striata; animal unable to stand, suffering from shock.

*Experiment* 6.

| TIME. | C. T. | R. T. |
|---|---|---|
| 11:12 A.M. | $74.50^{\circ}$ | $101\frac{2}{8}^{\circ}$ |
| 12:12 P.M. | | $102\frac{2}{8}^{\circ}$ |
| 1:35 P.M. | | $102\frac{3}{8}^{\circ}$ |
| 3:05 " | | $104^{\circ}$ |
| | | $1\frac{5}{8}^{\circ}$ |

Rabbit: weight $3\frac{1}{50}$ lbs. Section through the middle of the optic thalami, but not completely down to their base.

*Experiment* 7.

| TIME. | C. T. | R. T. |
|---|---|---|
| 4:13 P.M. | $78.90^{\circ}$ | $105\frac{4}{8}^{\circ}$ |
| 5:13 " | | $105\frac{6}{8}^{\circ}$ |
| 5:57 P.M. | | $104\frac{1}{8}^{\circ}$ |
| 6:17 " | | $106\frac{6}{8}^{\circ}$ |
| | | $1^{\circ}$ |

Rabbit: weight $2\frac{25}{50}$ lbs. Section just behind the corpora striata.

*Experiment* 8.

| TIME. | C. T. | R. T. |
|---|---|---|
| 1:10 P.M. | 75.67° | $99\frac{5}{8}^{\circ}$ |
| 2:10 " | | $101\frac{6}{8}^{\circ}$ |
| | | |
| 2:51 P.M. | | $98\frac{3}{8}^{\circ}$ |
| 3:51 " | | $103\frac{5}{8}^{\circ}$ |
| | | $1\frac{7}{8}^{\circ}$ |

Cat: weight $2\frac{33}{50}$ lbs. Transverse section dividing the corpora striata from the optic thalami, grazing sharply the thalami.

*Experiment* 9.

| TIME. | C. T. | R. T. |
|---|---|---|
| 12:50 A.M. | 74.00° | $101\frac{5}{8}^{\circ}$ |
| 1:50 " | 75.30° | $102\frac{5}{8}^{\circ}$ |
| | | 1° |
| 2:43 P.M. | | $97\frac{3}{8}^{\circ}$ |
| 3:57 " | | $99\frac{3}{8}^{\circ}$ |
| | | $3\frac{2}{8}^{\circ}$ |

Cat: weight $2\frac{5}{50}$ lbs. Convolutions of right side of brain broken up.

*Experiment* 10.

| TIME. | C. T. | R. T. |
|---|---|---|
| 2:00 P.M. | 78.50° | $99\frac{7}{8}^{\circ}$ |
| 3:15 " | | $100\frac{2}{8}^{\circ}$ |
| | | |
| 4:59 P.M. | | 100° |
| 5:54 " | | $102\frac{2}{4}^{\circ}$ |
| | | $2\frac{2}{8}^{\circ}$ |

Kitten: weight $2\frac{25}{50}$ lbs. Section dividing the corpora striata from the optic thalami.

*Experiment* 11.

| TIME. | C. T. | R. T. |
|---|---|---|
| 1:24 P.M. | 86.70° | $101\frac{4}{8}^{\circ}$ |
| 1:40 " | | $101\frac{9}{16}^{\circ}$ |

| | | |
|---|---|---|
| 4:00 P.M. | | $103\frac{3}{16}^\circ$ |
| 5:00 " | | $103\frac{5}{8}^\circ$ |
| | | $2\frac{1}{10}^\circ$ |

Cat: weight $6\frac{34}{50}$. Section behind the corpora striata. On the next day after the operation the following experiment was made:

| | | |
|---|---|---|
| 2:15 P.M. | $93.00^\circ$ | $103\frac{1}{2}^\circ$ |
| 3:15 " | | $103\frac{1}{2}^\circ$ |
| | | $1\frac{14}{16}^\circ$ |

*Experiment* 12.

| TIME. | C. T. | R. T. |
|---|---|---|
| 3:10 P.M. | $92.30^\circ$ | $102^\circ$ |
| 4:10 " | | $104\frac{3}{8}^\circ$ |
| 6:41 P. M. | | $98^\circ$ |
| 7:41 " | | $98^\circ$ |

Cat: weight $4\frac{35}{50}$lbs. Section through the middle of the corpora striata.

*Experiment* 13.

| TIME. | C. T. | R. T. |
|---|---|---|
| 12:18 P.M. | $76.5^\circ$ | $103\frac{1}{8}^\circ$ |
| 1:18 " | | $102\frac{4}{8}^\circ$ |
| 3:14 P.M. | | $101\frac{5}{8}^\circ$ |
| 4:29 " | | $101\frac{5}{8}^\circ$ |
| | | $-\frac{7}{8}^\circ$ |

Cat: destruction of convolutions anterior, to sulcus cruciatus. Weight $7\frac{25}{50}$ lbs.

*Experiment* 14.

| TIME. | C. T. | R. T. |
|---|---|---|
| 10:32 A.M. | $54.0^\circ$ | $103\frac{1}{8}^\circ$ |
| 11:32 " | | $103\frac{1}{8}^\circ$ |

Cat: sulci cruciati destroyed. Next day the following observations were made:

| | | |
|---|---|---|
| 11:5 A.M. | 75.0° | $103\frac{1}{8}$° |
| 12:5 P.M. | | $103\frac{1}{8}$° |

A section was now made through the middle of corpora striata.

| | | |
|---|---|---|
| 1:42 P.M. | 75° | $101\frac{5}{8}$° |
| 2:42 " | | $103\frac{5}{8}$° |
| | | $+\frac{4}{8}$° |